Respiratory symptoms and impairment in shipyard welders and caulkers/burners

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ABSTRACT All 607 men, aged 17 to 69, comprising a stratified sample of workers from one shipyard completed a respiratory questionnaire, clinical examination, and detailed spirometry. Chest radiographs were available on 332 men. Among the men aged 50–69 the prevalence of persistent cough and phlegm (chronic bronchitis) was 40%, of wheeze on most days 25%, and undue breathlessness on exertion 25%. After allowing for age the relative risk of welders and caulkers/burners having these symptoms were respectively 2.8, 2.2, and 3.1 compared with other shipyard tradesmen. The effects were of comparable magnitude to and interacted with those of current smoking. Among the welders and caulkers/burners who smoked, the relative risk of developing chronic bronchitis or undue breathlessness was related to the average fume exposure; the relative risk of wheeze was related to the average fume exposure in all smoking categories, with the strongest association in the ex-smokers. The occurrence of wheeze was also associated with a history of previous metal fume fever. A history of pleurisy but not of pneumonia was related to the fume exposure in the welders. After allowing for age and stature, forced expiratory volume (FEV1) was on average higher in young welders (age < 30) than other tradesmen. In welders and caulkers/burners who were current or ex-smokers, FEV1 and PEF were reduced in relation to the average fume exposure (mean reductions respectively 0.25 l and 0.99 l s⁻¹). The FEV1% (of forced vital capacity), the flow rates at small lung volumes (MEF50%FVC and MEF25%FVC), the mean transit time, and its standard deviation were also reduced by fume exposure or the declines with age were increased, or both. No impairment was demonstrable in the non-smokers and many men had given up smoking with apparently beneficial results. The occupational component of the respiratory impairment related mainly to exposures in the past; information was needed on the effects of present conditions in the industry.

In NE England ships are made from mild steel. The sheets are joined by welders who normally use flux covered electrodes (manual metal arc welding). Burners, whose trade is linked to that of caulkers, buff and burn off any metal protruding from the completed welds; they also gouge and cut the welded plates. Both groups of tradesmen are exposed to fumes from the weld metal (iron with an admixture of other substances), flux, coating materials, and solvents; the men may also inhale carbon monoxide, nitrogen dioxide, ozone, and cigarette smoke. Asbestos from lagging was formerly an additional hazard but this is now mainly a problem of ship repairing and breaking. Respiratory protection is by local exhaust ventilation or air supplied respirators; these measures are of recent origin and not universally applied. Compared with other shipyard tradesmen the welders have a raised standardised mortality ratio from pneumonia, and the caulkers/burners from pneumonia and chronic bronchitis. The forced expiratory volume has been reported as either normal⁶ or reduced by welding fumes in association with smoking.¹⁴ The evidence up to 1979 has been reviewed by Newhouse and Murray.⁵ Recent studies have suggested that at least some of the respiratory morbidity and mortality among welders is due to asbestos⁶ whereas, except in

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the case of stainless steel, the role of welding fumes is believed to be relatively unimportant. In one study where the opposite conclusion was reached the control group was inappropriate. Among ship maintenance and repair workers at Devonport dockyard, welders had prolonged sickness absences from respiratory infections. Compared with these men the welders who build ships may experience higher concentrations of fumes from working in the double bottom of ships and other confined spaces. Among such men the forced expiratory volume and transfer factor of non-smoking welders have been reported as reduced but sampling was not systematic and the controls were office staff not tradesmen. The present study at the same shipyard assesses the situation in greater detail.

**Subjects and methods**

The shipyard population was defined as all men on the payroll at 31 December 1978 plus the 37 welders who had left during the preceding nine years. Of the latter, 14 were dead, 10 had retired, and 13 had left for other reasons. A sample was drawn comprising all men aged 45 or over whose current or last occupation was as a welder or caulkers/burner, 50% of welders and caulkers/burners aged less than 45, all the tack welders, and 5% of other tradesmen, including riveters, fitters, electricians, and carpenters. Sampling was by random selection. Subsequently all foreman welders and plumber welders (20 of each) and two plater operators of fairing equipment were added to the survey population. After the survey the men who had ever been a welder, or failing that, a caulkers/burner, were included under one of these headings (table 1). Information was incomplete (usually from omissions during a domiciliary visit) in approximately 5% of men; a similar proportion refused to participate. Subjects completed an employment questionnaire, then were seen by one of four physicians (ELF, VJM, JHRR, FSR). They filled in a detailed questionnaire based on the MRC questionnaire on respiratory symptoms and McMillan's dockyard survey questionnaire; questions were asked on anginal symptoms. The men underwent a clinical examination.

Stature was measured with a Harpenden stadiometer, body mass with a calibrated beam balance, and skinfold thickness at four sites with Holtain skin calipers; the measurements were used to estimate fat free mass and percentage body fat. Trunk dimensions were also obtained but did not contribute usefully to the analysis.

The forced expiratory volume (FEV1) and vital capacity (FVC) were obtained by one of two experienced observers each using a McDermott bellows spirometer with digital display and incremental volume output (10 ms increments); the spirometers were calibrated four times daily. The subjects made two practice expirations, then three technically satisfactory results were obtained, and the highest value for each index was analysed. Spirometric results obtained on 27 men during domiciliary visits by other observers were not included in the analysis (see results). Flow volume curves were displayed on a JJ XY recorder and inspected at the time for shape and consistency. The information was recorded on a Sony 2 channel tape recorder. Tapes were analysed using a Hewlett Packard 9825 computer and printer. Peak expiratory flow rate was the mean over 30 ms (PEFR); other flow rates were taken at the point when 50% and 25% of FVC remained to be expired (MEF50,FVC and MEF25,FVC respectively). Transit time indices were the mean (MTT) and the standard deviation (SDTT). Expiration was considered to have started after expiration of 100 ml and to have ended when the volume expired in 0.5 s did not exceed 25 ml or, for the transit times, when the expiration had continued for 6 s. The two curves having the highest FVC were analysed; for the flow indices the higher of the two results was used, provided that the curves were of acceptable shape (see results), the FVCs agreed to within 5%, and the peak flow rates to within 10%. When this criterion was not met the result was taken from the expiration with the higher FVC. The transit time indices were taken from the expiration with the shorter mean transit time of the two which were analysed.

Chest radiographs were available for 332 men; most were taken during a radiographic survey in 1977 and the remainder at the time of the study—that is, two years later. Three independent observers read each film for round and irregular small opacities and other abnormalities using the ILO International Classification of Pneumoconioses. Majority readings were subsequently extracted by the authors and the profusion scores 0/- and 0/0 were amalgamated.

### Table 1  Study population analysed by trade

<table>
<thead>
<tr>
<th>Age range (y)</th>
<th>No in sample</th>
<th>No with complete data*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welders:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>105</td>
<td>179</td>
</tr>
<tr>
<td>Ex-employees</td>
<td>37</td>
<td>361</td>
</tr>
<tr>
<td>Foremen</td>
<td>20</td>
<td>114</td>
</tr>
<tr>
<td>Plumbers</td>
<td>20</td>
<td>117</td>
</tr>
<tr>
<td>Tack welders</td>
<td>70</td>
<td>106</td>
</tr>
<tr>
<td>Other tradesmen</td>
<td>85</td>
<td>105</td>
</tr>
<tr>
<td>Total</td>
<td>686</td>
<td>607†</td>
</tr>
</tbody>
</table>

*After reclassifying as welders or caulkers/burners men who subsequently moved to other trades.
†Of 79 lapses, 14 were dead, 34 had refused, and 31 had incomplete data.
A year after the survey, a subsample comprising the men with wheeze on most days, breathlessness grade 3 or above, or impaired lung function were reassessed, together with a sample of other men. The results obtained were used to check the stability of those of the main survey. The survey results after checking were transferred to an ICL 2966 computer running under the George 3 operating system. A preliminary descriptive analysis was undertaken and for each man indices of exposure to fumes as a welder or caulker/burner and reference values for FEV1 were calculated. The exposure indices for welders were W1 ever a welder, W2 years welding, W3 total fume exposure; this was the sum of the duration of each period of work as a welder multiplied by the proportion of time spent in confined spaces (<25% of time, 25–75%, >75% of time), W4 discounted fume exposure was as for W3 but with additional weighting given to exposure in the distant past, W5 accumulated fume exposure was as for W3 but additional weighting given to recent exposure. Average exposure (AE) was total fume exposure (W3) divided by duration of exposure. Similar indices were calculated for caulker/burners (C/B 1–5) and tack welders. Ever a welder or caulker/burner provided an overall index of fume exposure.

Results were entered into a multivariate analysis as either continuous or dummy variables (present or absent). The latter included exposure indices W1 and C/B1, smoking or ex-smoking, previous pneumonia or pleurisy, asbestos exposure, and cough with phlegm for more than three months in the year; the latter symptoms were evidence for simple chronic bronchitis (MRC,19). Wheeze was scored on the 3 point scale, (3) absent, (2) present occasionally, or (1) present on most days or nights. Breathlessness was analysed using an extended scale based on the clinical grades of Fletcher.18 Multiple regression and logistic regression analyses were performed using an IBM 370 computer, the computer package GLIM (Numerical Algorithms Group, Oxford), the Statistical Package for the Social Sciences (SPSS) of the University of Michigan,19 and BMDP statistical software.20 The dependent variables in the regression analyses were the lung function indices, the category of pneumoconiosis, and the respiratory symptoms. The independent variables were stature, mass/stature2, age, smoking, ex-smoking, previous chest illnesses, and exposure to asbestos; the effects of exposure to fumes from welding or burning were assessed in terms of average exposure for welders and caulker/burners alone, and of trade as a welder or caulker/burner when comparison was made with men in other trades. Tack welders were excluded from the latter comparisons. For analyses including interaction terms the variables, age and average exposure, were centred about their mean values.

Multiple regression analysis was performed using a forward stepwise method, the independent variable giving the largest reduction in the residual sum of squares being selected first. The exception was the exposure variable which was fitted after the other important variables had been included in the model. The analysis was carried out both without and with allowance for possible interaction between age, smoking, and exposure. The regression coefficients were considered to be significant at the 5% level of probability. The results of the logistic regression were reported in terms of the relative risk compared with unity which implied no contribution from the variable in question.

Results

DESCRIPTION OF SUBJECTS

The welders or caulker/burners in the survey population had a wide range of exposure to fumes. The exposure indices W2 through to W4 and CB2 to CB4 were highly correlated with age; the indices W5 and CB5 were weakly correlated, whereas the average exposure (AE) was independent of age. Accordingly this latter index was used in the analysis; the mean values and standard deviations for welders and caulker/burners respectively were 1.93 (0.60) and 1.87 (0.54) units. The interaction term, AE x age (based on centred variables), was independent of age and only weakly correlated with AE (r = 0.095) so all three terms could be included together in the multiple regression analyses. Among the survey population there were no former coalworkers or quarry men. Exposure to asbestos occurred from working alongside laggers (399 men), using asbestos cloth (79 men), working as a limpet sprayer (53 men), or working as a lagger (35 men). Of the welders and tack welders, 71% had experienced ray burns or arc eye; 35% of the welders and 29% of the caulker/burners had had metal fume fever associated with exposure to zinc. Fifty six per cent of participants were current cigarette smokers, 16% had never smoked (table 2). The amount currently smoked was independent of age and trade (mean value 21.7 g/day, range 1–70 g). The proportion of ex-smokers among the survey population (table 3) and among the welders but not the caulker/burners separately was significantly higher than expected for men in this social class in the United Kingdom. Of the men for whom there were chest radiographs, 22 (6.6%) had simple pneumoconiosis grade 2/1 or above. A history of pleurisy or pneumonia or chest injury or haemoptysis was given by 8–16% of men. Four per cent experienced exercise related discomfort suggestive of angina; 12 of these men (out of 23) were subsequently studied in detail and notable ischaemic heart disease was present in one. Three per cent of the men had had tuberculosis and 25% had kept pigeons
Respiratory health of shipyard welders and caulker/burners

Table 2  Percentage of respiratory symptoms and smoking habits by age group*

<table>
<thead>
<tr>
<th>Age group (y)</th>
<th>20–29</th>
<th>30–39</th>
<th>40–49</th>
<th>50–59</th>
<th>60–69</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>64</td>
<td>86</td>
<td>100</td>
<td>262</td>
<td>26</td>
</tr>
<tr>
<td>Cough and phlegm &gt; 3/12</td>
<td>21.9</td>
<td>20.9</td>
<td>32.5</td>
<td>37.8</td>
<td>50.0†</td>
</tr>
<tr>
<td>Wheeze:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>26.6</td>
<td>36.0</td>
<td>39.4</td>
<td>41.2</td>
<td>30.8</td>
</tr>
<tr>
<td>(ii)</td>
<td>7.8</td>
<td>16.3</td>
<td>16.9</td>
<td>26.3</td>
<td>26.9†</td>
</tr>
<tr>
<td>Total</td>
<td>34.4</td>
<td>52.3</td>
<td>56.3</td>
<td>67.5</td>
<td>57.7</td>
</tr>
<tr>
<td>Breathlessness:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 3</td>
<td>1.6</td>
<td>7.0</td>
<td>13.8</td>
<td>21.4</td>
<td>19.2†</td>
</tr>
<tr>
<td>Grade 4–5</td>
<td>0</td>
<td>1.1</td>
<td>0.6</td>
<td>4.2</td>
<td>19.2†</td>
</tr>
<tr>
<td>Total</td>
<td>1.6</td>
<td>8.1</td>
<td>14.4</td>
<td>25.6</td>
<td>38.4</td>
</tr>
<tr>
<td>Smokers:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cigarettes</td>
<td>57.8</td>
<td>46.6</td>
<td>53.1</td>
<td>60.1</td>
<td>61.5</td>
</tr>
<tr>
<td>Other</td>
<td>3.1</td>
<td>2.3</td>
<td>1.3</td>
<td>2.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>60.9</td>
<td>48.9</td>
<td>54.4</td>
<td>62.2</td>
<td>65.4</td>
</tr>
<tr>
<td>Ex-smokers</td>
<td>17.2</td>
<td>24.4</td>
<td>25.6</td>
<td>29.0</td>
<td>26.9</td>
</tr>
<tr>
<td>Never smoked</td>
<td>21.9</td>
<td>26.7</td>
<td>20.0</td>
<td>8.8</td>
<td>7.7</td>
</tr>
</tbody>
</table>

* Nine men aged < 20 are omitted from this table.
† Significant relation to age (p < 0.05); a more complete analysis is given in the text.

or budgerigars, but none had evidence of bird fanciers’ lung. Chronic bronchitis (MRC) was recorded by 33% of men, 21% recorded wheeze on most days or nights, 18% admitted to breathlessness grade 3 or more, and 11% had a reduced FEV₁ (< 2 SD). The prevalence of these abnormalities was related to age (table 2 and fig 1). Mean results for some anthropometric and lung function measurements are given in table 4.

RESPIRATORY SYMPTOMS

The principal determinant of chronic bronchitis was smoking which, after allowing for age and trade, was associated with a threefold increased risk compared with non-smokers and ex-smokers (relative risk 3.2, 95% confidence limits 2.1–4.6). The risk of chronic bronchitis increased with age and with physique, the short heavy subjects being more at risk than subjects with a low value for mass/st². After allowing for age and current smoking, work as a welder or caulker/burner was associated with an increased risk of chronic bronchitis compared with other trades (relative risk 2.8 (1.4–5.5)). In addition there was significant interaction between the effects of smoking and of welding fumes. Among welders and caulker/burners who smoked, the increased risk of chronic bronchitis was related to the average fume exposure. For the combined non-smokers and ex-smokers, the risk associated with the welding trades was also increased, but the increase was not relative to the average exposure and there was no association with trade when ex-smokers and non-smokers were examined separately (table 5 and fig 2). The non-smoking other tradesmen, however, comprised only 19 men. Previous pneumonia or pleurisy were significant antecedents of chronic bronchitis. The occurrence of pneumonia was related to age but was independent of the other variables, including fume exposure. Pleurisy was related to age in the welders; for the whole shipyard population it was also related to smoking, stature, and systolic blood pressure. In welders, after allowing for age, the prevalence of pleurisy was related to the average exposure.

Table 3  Numbers of men in different smoking categories by age groups compared with United Kingdom averages for social class III manual workers (Tobacco Advisory Council, 1980)

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>25–34</th>
<th>35–49</th>
<th>50–64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current smokers: (any product)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>40</td>
<td>117</td>
<td>177</td>
</tr>
<tr>
<td>Expected</td>
<td>44.0</td>
<td>123.4</td>
<td>189.7</td>
</tr>
<tr>
<td>Ex-smokers*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>16</td>
<td>56</td>
<td>82</td>
</tr>
<tr>
<td>Expected</td>
<td>9.4</td>
<td>42.9</td>
<td>62.5</td>
</tr>
<tr>
<td>Non-smokers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed</td>
<td>15</td>
<td>47</td>
<td>25</td>
</tr>
<tr>
<td>Expected</td>
<td>17.8</td>
<td>49.5</td>
<td>32.7</td>
</tr>
</tbody>
</table>

* Excess of ex-smokers was significant (χ² = 21.52, p < 0.001).

![Graph showing prevalence of chronic bronchitis and breathlessness](http://oem.bmj.com/)

Fig 1  Prevalences of chronic bronchitis, breathlessness grade 3 or above, and wheeze occasionally or on most days in relation to age.
among the welders and caulker/burners whose results were included in the analysis summarised in table 8 are given in parentheses (n = 360–371 for the different indices).

<table>
<thead>
<tr>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (a)</td>
<td>574</td>
<td>46-0</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>568</td>
<td>75-7</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>574</td>
<td>1-71</td>
</tr>
<tr>
<td>Body mass/stature 2 (kg m⁻²)</td>
<td>568</td>
<td>25-7</td>
</tr>
<tr>
<td>Forced expiratory volume (l)</td>
<td>575</td>
<td>3-10</td>
</tr>
<tr>
<td>Forced vital capacity (l)</td>
<td>575</td>
<td>4-36</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td>575</td>
<td>7-06</td>
</tr>
<tr>
<td>Peak expiratory flow (l/s⁻¹)</td>
<td>575</td>
<td>8-88</td>
</tr>
<tr>
<td>Maximal expiratory flow: (l/s⁻¹)</td>
<td>572</td>
<td>3-62</td>
</tr>
<tr>
<td>MEF₂₅/FVC</td>
<td>573</td>
<td>1-16</td>
</tr>
<tr>
<td>MEF₂₅/FVC</td>
<td>573</td>
<td>1-16</td>
</tr>
<tr>
<td>Mean transit time (s)</td>
<td>553</td>
<td>0-785</td>
</tr>
<tr>
<td>SDTT (s)</td>
<td>553</td>
<td>0-98</td>
</tr>
</tbody>
</table>

The occurrence of wheeze occasionally and wheeze on most days or nights were initially analysed separately but with similar results; the two were combined for the following account. Wheeze was related to age, current smoking, systolic blood pressure, chronic bronchitis, and previous metal fume fever. From logistic regression analysis of wheeze on age, current smoking, and trade, the relative risk for current smokers compared with non-smokers and ex-smokers was 2-7 (1-9-3-9), and the relative risk associated with the trade of welder or caulker/burner was 2-2 (1-3-3-7). In addition, for all smoking categories of welders and caulker/burners there was a significant dependency of wheeze on average fume exposure. There was also significant interaction between smoking and trade. Considering individual smoking categories the relation with fume exposure was strongest in the case of caulker/burners who were ex-smokers (table 6); it was no longer significant when allowance was made for co-existing chronic bronchitis. Among welders and caulker/burners, after

allowing for age, smoking, and average exposure, a history of metal fume fever carried an increased risk of wheeze (relative risk in smokers and non-smokers as a group, 2-3 1-4-3-8).

The grade of breathlessness in the survey population was associated positively with chronic bronchitis, age, mass/stature ², current or ex-smoking, pleurisy, exertional chest discomfort, and wheeze; it was negatively associated with stature. After allowing for age, stature, mass/stature ², and chronic bronchitis, the risk of breathlessness grade 3 or above was increased in welders and caulker/burners compared with other tradesmen. The risk was not independent of smoking category; among current smokers the relative risk was 3-2 (1-1-9-9) but there was no detectable increased risk for non-smokers or ex-smokers, either separately or in combination (table 7). For the welders and caulker/burners who smoked the increased risk of breathlessness was related to the average fume exposure. The breathlessness was associated with chest discomfort during exercise.

**X ray category of simple pneumoconiosis (small opacities)**

The 332 men on whom chest radiographs were available were predominantly welders (63%), caulker/burners, and other tradesmen (37%).

**Table 5 Relative risk of chronic bronchitis in welders (W) or caulker/burners (C/B) compared with other tradesmen (OT). Allowance made for age**

<table>
<thead>
<tr>
<th>Relative risk with 95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers</td>
</tr>
<tr>
<td>W &gt; OT</td>
</tr>
<tr>
<td>CB &gt; OT</td>
</tr>
<tr>
<td>W or C/B &gt; OT*</td>
</tr>
</tbody>
</table>

TNS = Term not significant.
*For all subjects allowing for age and current smoking 2-8 (1-4-5-5).
†Significant association with average fume exposure in welders and caulker/burners, independent of metal fume fever.

**Figure 2 Prevalences of respiratory symptoms in men who had ever smoked, subdivided by trade (welders and caulker/burners (W + C/B) or other tradesmen (OT)) and by smoking category (smokers (S) or ex-smokers (ExS)).**

**Table 7 Relative risk of wheeze in welders (W) or caulker/burners (C/B) compared with other tradesmen (OT). Allowance made for age**

<table>
<thead>
<tr>
<th>Relative risk with 95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers</td>
</tr>
<tr>
<td>W &gt; OT</td>
</tr>
<tr>
<td>CB &gt; OT</td>
</tr>
<tr>
<td>W or C/B &gt; OT*</td>
</tr>
</tbody>
</table>

TNS = Term not significant.
*For all subjects allowing for age and current smoking 2-2 (1-3-3-7).
†Significant association with average fume exposure in welders and caulker/burners, independent of metal fume fever.
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Table 7  Relative risk of breathlessness grade 3 or above in welders (W) or caulkers/burners (C/B) compared with other tradesmen (OT). Allowance made for age

<table>
<thead>
<tr>
<th>Relative risk with 95% confidence interval</th>
<th>Smokers</th>
<th>Ex-smokers</th>
<th>Non-smokers</th>
</tr>
</thead>
<tbody>
<tr>
<td>W &gt; OT</td>
<td>2.9(1.0-9.8)</td>
<td>TNS</td>
<td>TNS</td>
</tr>
<tr>
<td>CB &gt; OT</td>
<td>5.6(1.4-21.2)</td>
<td>TNS</td>
<td>TNS</td>
</tr>
<tr>
<td>W or C/B &gt; OT*</td>
<td>3.2(1.1-9.9)</td>
<td>TNS</td>
<td></td>
</tr>
</tbody>
</table>

TNS = Term not significant.
*For all subjects allowing for age 31 (1.3-7.7).
†Significant association with average fume exposure in welders and caulkers/burners, independent of metal fume fever.

burners (19%), and tack welders (5%). They were on average similar to the remainder in respect of age, fume exposure, FEV1, and all the attributes given in table 2. Before statistical analysis the results for 13 men whose chest radiographs showed notable abnormalities other than pneumoconiosis were excluded and 12 data sets were excluded on account of one or more missing items. Among the remaining 307 men were 20 in whom the profusion of small opacities was 2/1 or above; in 13 the opacities were round, in six predominantly round, and in one predominantly irregular. Among the exclusions were two with category 2/1 or above; in both the opacities were round. The profusion of small opacities was related to age and exposure to welding fumes; together these variables accounted for 18% of the variance. There were no associations with smoking, respiratory symptoms, or impaired lung function.

LUNG FUNCTION

Complete results were obtained on nearly all subjects other than the 27 men who were seen at home; on these men, flow volume curves were not recorded. In addition, in many instances the FEV1 or FVC was materially lower than at the 12 month follow up. Accordingly, the results for men seen at home were not included in the analysis. Also excluded were the flow volume results for 22 men with atypical curves; the latter exclusions did not influence the findings. The FEV1 was related positively to stature and negatively to age, current or ex-smoking, systolic blood pressure, chronic bronchitis, wheeze, previous pleurisy, and previous pneumonia. Fume exposure was also related to some of these variables (see above) so when examining its possible association with impaired lung function allowance was made only for the independent variables age, stature, and smoking. The analysis was confined to the welders and caulkers/burners as in these men the lung function could be related to the average fume exposure; significant associations were observed in the smokers and ex-smokers as separate groups but not in the non-smokers. Among welders and caulkers/burners who were smokers or ex-smokers the average fume exposure contributed to the description of all the indices obtained by dynamic spirometry except FVC; either or both the absolute level was reduced and the decline with age was increased. When the whole analysis was repeated including the non-smokers, a similar result was obtained (table 8). For most of the indices of lung function the ex-smokers had significantly better lung function than the smokers. The adverse effect of smoking, however, was not related to the number of cigarettes currently smoked a day. Among the smokers the results did not differ as between the welders and caulkers/burners. By contrast, among the non-smokers and ex-smokers, after allowing for age and stature, the welders had higher values for peak expiratory flow rate (ΔPEF 0.96 l s⁻¹) and forced expiratory volume (ΔFEV1 0.23 l) than the caulkers/burners. In addition, among the shipyard workers aged less than 30, the FEV1 was 9% higher among the welders than the other tradesmen, despite the two groups having similar age, stature, and tobacco consumption.

Discussion

This study describes the respiratory health of current shipyard workers and surviving welders or caulkers/burners from among those who had left within the

Table 8  Multiple regression equations describing indices of airflow limitation in welders and caulkers/burners who had ever smoked. Age and AE were treated about their mean values (table 4); (For abbreviations, see methods)

<table>
<thead>
<tr>
<th>Regression coefficient</th>
<th>FEV1 (l)</th>
<th>FVC (l)</th>
<th>FEV%* (%)</th>
<th>PEF (l s⁻¹)</th>
<th>MEF25-75% FVC* (l s⁻¹)</th>
<th>MEF50-75% FVC* (l s⁻¹)</th>
<th>MTT* (s × 10⁻³)</th>
<th>SDTT* (s × 10⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (× 10⁻³)</td>
<td>-36</td>
<td>-34</td>
<td>-415</td>
<td>-76</td>
<td>-63</td>
<td>-36</td>
<td>7.2</td>
<td>8.9</td>
</tr>
<tr>
<td>Stature (m)</td>
<td>5.03</td>
<td>7.70</td>
<td>-15.2</td>
<td>8.13</td>
<td>4.21</td>
<td>1.41</td>
<td>-66</td>
<td>-6</td>
</tr>
<tr>
<td>Average exposure (AE)</td>
<td>-0.13</td>
<td>-3.28</td>
<td>-0.52</td>
<td>-31†</td>
<td>-10†</td>
<td>5.6</td>
<td>4.7†</td>
<td></td>
</tr>
<tr>
<td>AE × age (× 10⁻³)</td>
<td>-304</td>
<td></td>
<td>-31†</td>
<td>-10†</td>
<td>5.6</td>
<td>4.7†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If ex-smoker</td>
<td>-2.94</td>
<td>0.57</td>
<td>0.48</td>
<td>0.18</td>
<td>-52</td>
<td>-52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>95.2</td>
<td>1.73</td>
<td>0.86</td>
<td>0.26</td>
<td>76.2</td>
<td>1019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEE</td>
<td>0.59</td>
<td>0.50</td>
<td>0.70</td>
<td>200</td>
<td>236</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² (%)</td>
<td>49.6</td>
<td>58.3</td>
<td>18.2</td>
<td>26.3</td>
<td>23.0</td>
<td>13.2</td>
<td>11.6</td>
<td></td>
</tr>
</tbody>
</table>

*Exposure terms also significant with non-smokers included in the equation (smoking scored 0, 1, 2 for non, ex-, and current smokers).
†Term significant in presence of AE which was not itself significant.
preceeding nine years. It throws no comparable light on
the men who died during the nine years or those who
left before that. In addition, no information was
obtained on the 5% of men who refused to participate;
however, their omission was unlikely to have
materially influenced the result. The exclusion from
the analysis of lung function of results obtained at
domiciliary visits led to the omission of some subjects
with material respiratory impairment, but this was
necessary if only reliable information was to be
analysed. The exclusion of current tack welders from
comparisons between men who had ever been welders
or caulk/burners and men in other trades was also
necessary on account of the fume exposure of tack
welders being intermediate between those of the main
groups. The effects of their exclusion were mainly
quantitative rather than qualitative.

QUALITY OF INFORMATION INCLUDED IN THE
ANALYSIS
The occupational histories were checked by
occupational nurses in the shipyards and again by the
chest physicians at clinical interview. Comparison
with information obtained subsequently on a sub-
sample of men showed that estimates of time spent
welding or caulk/burning in confined spaces
(<25%, 25–75%, >75%) were rather variable but
otherwise the occupational histories were consistent.
This was also the case for the answers to respiratory
questions in men whose circumstances had not
changed in other respects—for instance, smoking
habit or medical treatment. The anthropometric
measurements were made using standard procedures;
some variation may have occurred in the
measurements of skinfold thickness and chest wall and
sternal lengths but these indices did not contribute
usefully to the results. The spirometry included in the
analysis was performed by two experienced observers
using identical equipment which was calibrated four
times daily. The three x-ray readers were also experi-
cenced; they used common standard and trigger films.
Thus the information obtained was of good quality
apart from the indices of exposure. The latter, as well
as having a rather poor reproducibility, also made no
allowance for the individual welders adopting
different postures or positions for the exhaust ventila-
tion hose. An attempt to improve the exposure indices
by incorporating information on heat exposure—for
instance, arc eye or skin burns—was unsuccessful as
the latter features failed to identify heavily exposed
men and no systematic personal sampling had been
carried out. Nevertheless, relatively crude information
of this type has been adequate to identify exposure
effects in other studies.

ASPECTS OF ANALYSIS
The original survey population was enlarged by the
inclusion of foreman welders and plumber welders; the
former had previously been welders and their exposure
to fume was estimated with an accuracy similar to that
for other men. The plumber welders had a different
exposure but they constituted fewer than 6% of men
classified as welders. Nine men were aged 20 or less,
hence their lungs were still growing and smaller than
predicted using the adult model relating lung function
to age. Only three were exposed to fumes (2 welders, 1
caulker/burner), however, so the error this introduced
into the analysis was small.

The numbers of men in subgroups defined by trade
and smoking category were adequate for the analyses,
except in the case of non-smoking other tradesmen;
this group comprised only 19 men.

A difficulty with the analysis was the high correla-
tion that obtained between age and many of the
exposure indices, also between the interaction terms
and their component variables. Principal component
regression analysis was considered as a means of
overcoming this source of error but rejected as the
resulting factors could not be interpreted precisely. In
the event error was minimised by confining the
analysis to uncorrelated variables. To this end average
exposure was used instead of total exposure and the
constituents of interaction terms were centred about
their mean values.

RESPIRATORY SYMPTOMS
Shipyard workers over the age of 50 were found to
have significant respiratory morbidity including
chronic bronchitis in 40% of men, wheeze on most
days or nights in 25%, and undue breathlessness on
exertion also in 25% of those in this age group. These
prevalences were similar to those observed in the 1950s
by Higgins and Cochrane in coalminers and foundry
workers but they were higher than have been repor-
ted in most other series. Breathlessness was the men's
principal complaint. It resulted from many factors,
some of which, such as chronic bronchitis and pleur-
isy, were themselves related to occupational fume
exposure. Omitting these and after allowing for age
and stature, there was a significant association be-
tween breathlessness and trade as a welder or caulk/ 
burner. The association was independent of chronic
bronchitis but was related to whether or not the men
had ever smoked. Among welders and caulk/burners
who were current smokers the likelihood of breathless-
ness was related to the fume exposure. The possible
reasons for the breathlessness are considered below.

Chronic bronchitis is traditionally associated with
occupations entailing exposure to dusts and fumes; the
average prevalence is usually reported as about double
that in other occupations but less than that due to
smoking. In the present study the relative risk of chronic bronchitis for welders and caulkers/burners was 2.8 times that for other tradesmen, and comparable with that of smoking. There was significant interaction between these two effects such that the likelihood of chronic bronchitis was significantly related to the average fume exposure in the smokers but not the non-smokers or ex-smokers, either separately or in combination (table 5). Thus there was strong evidence that the fumes affected the lungs of smokers and that the large number of welders who abandoned smoking benefited by so doing. This possibility was suggested by Barhad and colleagues. Chronic bronchitis, together with age and smoking, were the principal factors associated with wheeze. After allowing for age and smoking, however, the occurrence of wheeze was related to the fume exposure; the association was strongest for the ex-smokers which suggested that, unlike in the case of chronic bronchitis, abandoning smoking did not bring relief from the fume related component of this symptom. Wheeze was more common in men with previous metal fume fever. Experience of this condition was reported equally often by welders and caulkers/burners who had ever smoked but by rather more non-smoking welders than caulkers/burners. The occurrence of metal fume fever was independent of the estimated average fume exposure but the estimate was probably influenced more by recent than previous exposure, so a real association could have been missed. Information on atopic status could have thrown light on the mechanisms. The study failed to confirm that welding fumes contributed to an increased prevalence of pneumonia, though this had been expected in the light of other evidence. The prevalence of pleurisy was increased, however. This was not due to concurrent exposure to asbestos. In addition, siderosis and sensitisation arising from keeping pigeons or budgerigars appeared not to have contributed to any of the abnormalities observed.

LUNG FUNCTION
The welders and caulkers/burners who had ever smoked were found to have exposure related narrowing of both large and small airways. The impairment associated with exposure was the same at all ages in the case of FEV1, and PEF but was greater in the older than the younger subjects for the FEV% maximal expiratory flow rates at small lung volumes, and the transit time indices. For all but the FEV1 where the separate results for welders and caulkers/burners were not significant, similar relations with fume exposure were obtained for smokers and ex-smokers and welders and caulkers/burners separately. In addition, the inclusion of non-smokers did not alter the significance of the coefficients on exposure, except marginally for FEV1 (p = 0.053). Thus the evidence for welding fumes contributing to airway narrowing in smokers and ex-smokers was internally consistent. The evidence for a similar effect in non-smokers was weak but this could have been due in part to this group only comprising 73 men. Among the smokers and ex-smokers, the average reductions in FEV1 and PEF associated with fume exposure were respectively 0.251 and 0.991 s⁻¹ which were 8% and 11% of the mean values. These changes were of similar magnitude to those associated with smoking compared with non-smoking (respectively 0.231 and 0.881 s⁻¹) and sufficient to cause breathlessness on exertion in some individuals, especially those who also had chronic bronchitis. For the other indices, the apparent bronchoconstrictor effect of fume exposure in men who had ever smoked increased with age. This could have been due to both the cumulative effect of prolonged exposure to lung irritants and higher fume exposures in the past. Similar changes would then have been expected for the FEV1 and PEF. That these were not observed might have been due in part to confounding factors. Thus the young welders had a higher mean FEV1 than the other tradesmen and among the current non-smokers, the welders had higher levels of PEF than the caulkers/burners. These changes could have been due in part to shipyard recruits of robust physique having been selected as welders and to welding possibly exerting a training effect on the accessory muscles of respiration. Selective loss from the shipyard population of men with respiratory impairment appeared not to have been a material factor in the years immediately preceding the study when the labour turnover was small. It became so subsequently, however, during a period when many men were laid off (paper in preparation) and its operation during the earlier period cannot altogether be ruled out. Full interpretation of the effect of these and other factors would require longitudinal study. Meanwhile, the present results provide internally consistent evidence for interaction between smoking and exposure to fumes as a welder or caulkers/burner causing chronic bronchitis, narrowing of both large and small lung airways, and breathlessness on exertion. The physical nature of the work might itself also exert a contributory effect; on the one hand, developing the accessory muscles of respiration and, on the other, in the case of work in confined spaces leading to loss of fitness for sustained work with the legs among men who did not also engage in active leisure time activities. The association of chronic bronchitis and narrowing of all classes of airways with fume exposure was consistent with the findings of the other studies cited but the association was stronger than in many of them. This could have been due to shipyard welders in confined spaces having higher fume exposures than
workers in dockyards where semi-confined spaces would have been more usual, or in factories where fixed exhaust ventilation was in use. This, however, is speculative in the absence of reliable measurements of personal fume exposure. The study provided no support for the view that occupational bronchitis was associated mainly with narrowing of large rather than small airways.\textsuperscript{30}

Other factors that contributed to the result were the availability of longitudinal measurements which provided evidence on quality control and rigorous exclusion of error due to collinearity from the statistical analysis. While the effect of fume exposure was relatively large, however, its nature was similar to that observed in other studies. The adverse effect of fumes was mainly confined to smokers and ex-smokers who formed the great majority of shipyard workers. A larger number of non-smokers would have been needed to explore fully the effects of fumes in this section of the workforce. On average the effect of fumes was similar to that of being a smoker. Whereas among the welders who smoked, however, the magnitude of the effect of smoking was independent of the number of cigarettes smoked a day, the effect of fume exposure was related to the average intensity but the gradient was relatively shallow. In the case of both FEV\textsubscript{1} and PEF the effect of being in the upper rather than the lower 5\% of the exposure range was associated with an average decrement of lung function of 1.5 times compared with 0.5 times that of smoking. In addition, the reductions with exposure in FEV\textsubscript{1}, MEF, and transit times were larger among the older men, which suggested that the respiratory impairment reflected mainly conditions in the past; it could then have been due to there having been no exhaust ventilation. In the case of FEV\textsubscript{1} and PEF the interaction term AE × age was not significant at the 5\% level, but with a p value of 0.07 it was not inconsistent with this hypothesis.

In view of these findings the present results appear to relate mainly to previous conditions in the industry. The effects of present day conditions and information on welding fumes in non-smokers must await the result of longitudinal studies on men only exposed to such conditions.

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Respiratory health of shipyard welders and caulk/burners


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J E Cotes, E L Feinmann, V J Male, F S Rennie and C A Wickham

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